Occupational Cancer in the United Kingdom

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Most of the known occupational hazards of cancer have occurred in the United Kingdom. Over recent decades a contraction of manufacturing industry and legal controls on carcinogens have led to reductions in exposure, but cases continue to occur, often as a consequence of exposures 20 or more years ago. By far the most important occupational cause of cancer in the United Kingdom is asbestos, which currently accounts for some 600 cases of mesothelioma and perhaps 100 cases of bronchial carcinoma per year. Recent trends suggest that the number of mesothelioma cases attributable to asbestos will increase over the next few decades. Exposure to sunlight in outdoor work may cause several hundred cases of nonmelanomatous skin cancer per year, and occupational exposure to polycyclic aromatic hydrocarbons could be responsible for a similar number of skin and lung tumors. Other known occupational hazards of cancer are unlikely to account for more than 100 cases per year in total. — *Environ Health Perspect* 107(Suppl 2):239–244 (1999). *http://ehpnet1.niehs.nih.gov/docs/1999/Suppl-2/239-244coggon/abstract.html*

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Most occupational hazards of cancer arise from the processes and products of manufacturing industry. Britain was the first country to undergo industrialization, and despite a recent rapid growth in service industries, it continues to produce a wide range of manufactured goods. Most of the known occupational carcinogens have occurred in British industry, and the country has been a fertile ground for the epidemiologic investigation of such hazards. Relatively large numbers of exposed workers have been available for study, and the facility for tracing people through the National Health Service Central Register has been an invaluable resource in retrospective investigations of mortality from cancer among industrial populations. The register includes all people who have been assigned to a National Health Service general practitioner at some time since 1946 (almost the entire national population), and enables death certificates to be obtained for those who have died. Where subjects' full names and dates of birth are available, trace rates are normally 98% or higher. The country Britain also has a long tradition of decennial national analyses of occupational mortality, and these provide further useful information on the impact of occupational carcinogens and trends in the incidence of the diseases that they cause.

The pattern of exposure to occupational carcinogens in the United Kingdom has changed over recent decades. This partly reflects changes in economic circumstances with the disappearance of industries that are no longer viable. For example, during the 1970s the exploitation of offshore resources of natural gas led to the demise of coal gas manufacture and elimination of the associated hazard of lung cancer. In addition, occupational carcinogens have come under increasingly strict legislative control.

Health and safety legislation in the United Kingdom is structured within a framework of European Community directives. It requires employers to identify hazards in the workplace, to assess the risks to health that they pose, and to take steps to control the risks where appropriate. For most carcinogens it also specifies maximum exposure limits. Where possible, control should be by elimination or substitution of the hazardous substance or process. For example, the use of 2-naphthylamine and related compounds in the dyestuffs industry was banned following demonstration that they carry a high risk of bladder cancer (*1*). Where total elimination is not practical, control should ideally be achieved by improvements in engineering or systems of work. The use of personal protective equipment is regarded only as a last resort.

The changes described would be expected to result in a long-term decline in most occupational cancers. However, because tumors often do not occur until many years after first exposure to a carcinogen, the effect is not yet complete, and cases continue to occur as a legacy of past practices. Moreover, controls have not always been adequate, and further cancers may result from other occupational hazards that have not yet been satisfactorily investigated. Occupational cancer therefore remains an important problem in the United Kingdom. The impact of individual carcinogens varies enormously.

Asbestos

Crocidolite, amosite, and chrysotile asbestos have all been used extensively in the United Kingdom. The main sources of occupational exposure have been in shipbuilding, railway engineering, the construction industry, and the manufacture of asbestos textiles and other asbestos products. Legal restrictions on asbestos exposure were first introduced in 1933, and have since been progressively tightened. Currently the control limits are 0.5 fibers/ml for chrysotile and 0.2 fibers/ml for other forms of asbestos, each averaged over any continuous period of 4 hr; and 1.5 and 0.6 fibers/ml, respectively, when averaged over 10 min. The import of crocidolite and amosite and of products containing them has been prohibited since 1984, but exposure continues to occur, for example, when crocidolite is removed from older buildings and industrial plants.

Asbestos causes pleural and peritoneal mesothelioma (*2*) and bronchial carcinoma (*3*). It has also been linked with several other cancers including carcinomas of the larynx and gastrointestinal tract (*4*), but these associations are not firmly established. Exposure to crocidolite and amosite, even of relatively short duration, can increase substantially the risk of mesothelioma, and most of the 1000 or so cases of mesothelioma that currently occur each year in Britain are likely to be attributable to asbestos. In some cases the exposure to asbestos will have occurred outside the workplace, but the majority of exposures are occupational.

This is reflected in patterns of mortality from pleural and peritoneal cancer by occupation (Table 1). Because mesothelioma is uniformly fatal, mortality provides a good proxy for incidence. The proportional mortality ratios (PMRs) shown in Table 1 are based on the most recent full-time occupation as recorded on the death certificate. Over the 11-year period analyzed, more than 850 excess deaths were recorded in the listed occupations, all of which are associated with exposure to asbestos. As the induction period for mesothelioma is often 30 years or longer from first exposure, the most recent occupation may not always be the one that is most relevant to the death, and the total number of occupational cases is likely to be substantially higher. Each year more than 500 new cases of mesothelioma are awarded compensation under the government's industrial injuries scheme (5).

Also notable in Table 1 is the different ranking of occupations for pleural and peritoneal cancers. For example, among construction workers not elsewhere classified, a group that includes laggers, there were 77 deaths from pleural cancer and 64 from peritoneal tumors. In contrast, carpenters, with a higher proportional mortality ratio (PMR) and a larger number of deaths from pleural cancer, had only 6

deaths from cancer of the peritoneum. This may indicate differences in the exposure–response relationships for the two tumors (6).

Mortality from mesothelioma in Britain is currently rising in a way that is unlikely to be explained simply by artifacts of improved diagnosis (7). The increase is most marked in the cohort of men born between 1943 and 1948, and by combining projections for separate birth cohorts, Peto and colleagues (7) have estimated that male mortality will peak in about the year 2020 when there will be between 2700 and 3300 deaths annually. The mortality pattern in women is more difficult to predict because they have fewer deaths, especially at young ages, which leads to greater statistical uncertainty. The epidemic appears to stem from occupational exposures during the 1960s and 1970s when imports of asbestos to the United Kingdom peaked. However, it is unclear whether the limits on exposure at that time were unsatisfactory or whether they were just inadequately enforced.

The relation of asbestos to bronchial carcinoma is much less specific than that to mesothelioma, making the impact of occupational exposure more difficult to assess. In particular, variation in incidence and mortality between occupations is confounded by

differences in smoking habits and sometimes by occupational exposure to other lung carcinogens. In cohort studies of asbestos workers, it has been observed that the excess of bronchial carcinoma cases may be twice that of mesothelioma (8), but these studies have focused on workers with relatively high exposures. The relation may be different at the lower levels of exposure, which are more common in the working population as a whole. Nevertheless, it is likely that each year tens or hundreds of cases of bronchial carcinoma in the United Kingdom are attributable to asbestos, even if only in the occupations with highest exposures.

Polycyclic Aromatic Hydrocarbons

Occupational exposure to polycyclic aromatic hydrocarbons (PAHs) is mainly by inhalation and skin contact. The heaviest exposures by inhalation have occurred in coke ovens, coal gas manufacture, and aluminum production by the Soderberg process, but lower exposures are widely encountered, for example, from combustion of diesel fuel (9). During the last 40 years, the major source of dermal exposure has been mineral oils, particularly in the engineering industry.

Inhalation of PAHs causes lung (10) and possibly bladder cancer (11). However, the resultant burden of disease is difficult to estimate because of uncertainties about the risks from the low levels of exposure that are most prevalent. Among workers with high exposures, such as those working on the topside in coke ovens, risk of lung cancer may be elevated 5-fold or more (12); however, at most only a few thousand people have worked in jobs of this kind, and they therefore account for relatively small numbers of cases. Occupational exposure to diesel fumes is much more common, but it is still uncertain whether it carries a material increase in risk of cancer (9).

Dermal exposure to PAHs causes nonmelanomatous cancer of the skin, and particularly squamous cell carcinoma (13). These tumors are rarely fatal, and therefore information about risk requires study of incident cases. For example, a study of 781 patients with squamous cell skin cancer in northwest England from 1967 to 1969 compared the frequency of jobs reported at interview with the distribution of occupations at censuses (14). An excess incidence was found in several occupations with potential exposure to PAHs, but information about specific

Table 1. Occupations with significantly elevated proportional mortality from cancer of the pleura or peritoneum—England and Wales, men 20 to 74 years of age, 1979–1980 and 1982–1990.[a]

Occupation	Cancer of pleura		Cancer of peritoneum	
	Deaths	PMR (95% CI)	Deaths	PMR (95% CI)
Metal plate workers	73	709 (556–892)	1	78 (2–432)
Vehicle body builders	24	649 (416–968)	4	877 (239–2246)
Plumbers and gas fitters	134	450 (377–533)	11	283 (141–506)
Upholsterers	16	366 (209–594)	0	0 (0–688)
Carpenters	167	362 (309–421)	6	102 (37–221)
Electricians	127	349 (291–415)	4	83 (23–212)
Electrical plant operators	14	301 (165–506)	0	0 (0–643)
Chemical engineers and scientists	13	274 (146–468)	0	0 (0–597)
Welders	56	247 (186–320)	1	33 (1–186)
Managers in construction	32	240 (164–340)	6	349 (128–759)
Boiler operators	24	240 (153–357)	2	171 (21–616)
Electrical engineers (so described)	31	227 (154–323)	1	58 (1–325)
Production fitters	192	208 (180–240)	12	103 (53–179)
Plasterers	18	207 (122–327)	3	265 (55–773)
Sheet metal workers	25	186 (120–274)	4	235 (64–602)
Builders and handymen	65	166 (128–212)	5	98 (32–229)
Professional engineers not elsewhere classified	53	162 (121–212)	2	46 (6–168)
Construction workers not elsewhere classified	77	160 (126–200)	64	990 (762–1265)
Dockers and goods porters	36	156 (109–216)	7	242 (97–500)
Chemical workers	39	144 (103–198)	5	146 (47–341)
Smiths and forgemen	6	133 (49–289)	3	561 (116–1639)
Machine tool operators	116	132 (109–158)	15	136 (76–224)

Abbreviations: CI, confidence interval; PMR, proportional mortality ratio. [a]Based on Coggon et al. (6).

exposures was not obtained. A recently established national reporting scheme for occupational skin disorders should soon provide better estimates of the frequency of occupational skin cancer from different causes, but at present this is an important gap in our knowledge.

Better information is available about scrotal cancers, which constitute only a small subset of all skin tumors but which carry a much higher fatality. In the past, scrotal cancer was an occupational hazard in chimney sweeps, cotton mule spinners, workers extracting shale oil, and wax pressmen (13), but these occupations have either disappeared or no longer pose an important risk. Most recently, the majority of occupational cases in the United Kingdom have been in metal machinists. Steps taken to control the risk have included the use of solvent-refined cutting oils with a reduced PAH content, and provision of splash guards and protective overalls. In a national analysis of occupational mortality for England and Wales during 1979 and 1980 and from 1982 to 1990, 17 out of 85 deaths from scrotal cancer were in metal machinists (15). However, all had been born before 1930, and thus could have worked in engineering before the above controls were implemented. In view of the actions that have been taken to reduce risk, the number of occupational scrotal cancers would be expected to decline further, perhaps even to zero, over the next 20 years.

Ionizing Radiation

Occupational exposure to ionizing radiation occurs in healthcare workers (especially radiographers and radiologists), industrial radiographers, laboratory scientists, employees in the nuclear industry, people working with luminous materials, and air crews (from cosmic radiation). In addition, miners of hematite in northwest England and of tin in the southwest were in the past exposed to radon, but apart from one small tin mine, these industries have now disappeared.

Most exposure to ionizing radiation has been tightly controlled for many years, and there is no demonstrable excess mortality from cancer, for example, in radiographers (16). The highest exposures are now in the nuclear industry, and cohort studies of nuclear workers have indicated an excess of leukemia (17). Again, however, the annual number of cases attributable to such exposure is likely to be small (fewer than 10).

Ultraviolet Radiation

The most important source of occupational exposure to ultraviolet radiation is sunlight. Artificial sources such as strip lights are widespread and have been linked with cancer in some studies (18), but the evidence for this association is not convincing.

Solar radiation causes both melanoma and other skin cancer. However, the relation to melanoma is complex. In Caucasians the disease is more common at low latitudes and in those who report frequent sunburn (19), but rates are not unusually high in outdoor occupations such as farmers (20). This has prompted the theory that risk arises from intermittent exposure to sunlight and that prolonged exposure with resultant tanning is protective. Alternatively, it may be that exposure during childhood is more relevant than that occurring later in life. The latter hypothesis is consistent with the observation that although overall mortality from melanoma among farmers in England and Wales is no higher than the national average, those living in the south of the country have higher rates than those in the north (21). Whatever the nature of the link, occupational exposure to sunlight does not appear to be a major cause of melanoma in the United Kingdom.

The position in relation to squamous and basal cell carcinomas of the skin is more straightforward in that nonmelanomatous skin cancer is clearly more common in people who work outdoors (14,22). It is uncertain how many cases in Britain are attributable to outdoor work, but such tumors are relatively common in the general population. It is possible that occupational exposure to sunlight is responsible for several hundred cases per year.

Aromatic Amines

Exposure to carcinogenic aromatic amines such as 2-naphthylamine used to occur in the manufacture of dyestuffs, rubber, and coal gas. Several of these compounds are potent bladder carcinogens, and at one time the lifetime risk of bladder cancer in occupations with heavy exposure was as high as 10 or even 20% (1). However, when the magnitude of the risk became fully apparent during the 1950s, their use in the dye and rubber industries was banned. Subsequently, production of coal gas also ceased. A cohort study of rubber workers followed up to 1975 suggested no excess risk of bladder cancer in those first employed after 2-naphthylamine was

withdrawn (23), and although cases continue to occur in people exposed in earlier years (making dyes or rubber), data from industrial injuries awards indicate that they are now few in number (less than 25 per year) (5).

Chromates

Inhalation of hexavalent chromium compounds causes bronchial carcinoma. The hazard was first demonstrated in the chrome pigment industry (24), but claims for industrial injuries benefits suggest that this now accounts for fewer than 10 cases per year (5). Other, more common sources of exposure to chromates are in the electroplating industry and from welding stainless steel.

A cohort study of British chromium platers followed from 1946 to 1983 found 72 deaths from lung cancer where 48.1 would have been expected from rates in the national population (25). This accords with a proportional mortality analysis for England and Wales during the 1980s that found a PMR of 126 for lung cancer in male electroplaters based on 134 deaths over 11 years (21). Because this was based only on most recent occupation, the total attributable mortality might be higher—perhaps as many as 5 or 10 cases more per year.

The occurrence of lung cancer in welders has been assessed in cohort studies in several countries, some of which have suggested an excess risk (26). However, it has not been clearly established that this is attributable to chromates rather than a confounding effect of smoking or other occupational exposures (e.g., to asbestos).

Nickel

The hazard of nasal and lung cancer in nickel refiners was first demonstrated among employees at a plant in South Wales. By 1958, 131 cases of cancer of the lung were known to have occurred in British nickel workers and 61 cases of nasal cancer (27). However, industrial hygiene was improved as early as the 1920s (27), and now the excess of cases has virtually disappeared, with only one or two compensated cases each year (5).

Arsenic

An excess of lung and skin cancer in manufacturers of sheep dip who were exposed to arsenic was first recognized in the 1940s (28) and later supported by similar findings in other workers with occupational exposure to arsenic, such as gold miners in Africa and vineyard workers in France

(29,30). However, the use of arsenic in sheep dip has long since disappeared and no longer gives rise to disease.

Arsenic also occurs as a contaminant in ores of copper, and elevated rates of lung cancer have been reported in copper smelters (30). Primary smelting of copper, however, is not currently carried out in the United Kingdom (31).

Wood Dust

Exposure to hardwood dust, mainly in the manufacture of furniture, has been an important cause of adenocarcinoma of the nose and nasal sinuses (32). Dusts from softwoods (which are widely used in the construction industry) may also cause nasal cancer, but with a lower relative risk (33). To counter this hazard, steps have been taken to reduce dust levels, particularly in furniture production.

Cases of nasal cancer continue to occur in excess among woodworkers. In a proportional mortality analysis based on death certificates, there were 39 deaths from these tumors from 1979 to 1980 and from 1982 to 1990 among male woodworkers in England and Wales where 18.2 would have been expected (20). However, these cases may well reflect exposures many years ago, before controls were implemented. In the future, incidence would be expected to decline.

Leather Dust

The hazard of nasal cancer from leather dust appears to be specifically from vegetable-tanned leather of the sort that is used to make the soles of boots and shoes (34,35). In Britain, most shoes now have soles made from synthetic materials, and the traditional construction using leather is restricted to the most expensive end of the market. Thus, exposure to the hazard is limited. Occupational mortality data (20) and industrial injury awards (5) again indicate that the resultant burden of disease is relatively small (one or two cases per year at most).

Vinyl Chloride Monomer

Vinyl chloride monomer is an intermediate in the production of polyvinyl chloride, and causes angiosarcoma of the liver. This cancer is normally extremely rare, and from 1979 to 1986, only 55 cases were recorded in all of England and Wales (36). Among these 55 cases, 10 had worked at vinyl chloride plants, suggesting an annual incidence of one to two occupational cases nationally. With

improvements in industrial hygiene, this rate would be expected to fall in the future.

Bischloromethyl Ether

Bischloromethyl ether is a hazard in the production of ion-exchange resins, and causes bronchial carcinoma (37). Only a few people in Britain have worked in this process, and from industrial injuries awards, it appears that the annual number of attributable cases is fewer than five (5).

Benzene

Benzene causes acute myeloid leukemia and possibly other lymphatic and hematopoietic cancers (38). In the past, relatively high exposures occurred from its use as a solvent, especially in the printing and rubber industries. However, in these applications other safer alternatives have now been substituted. As a consequence, the main source of occupational exposure today is petrol (gasoline). Petrol in Britain currently contains 2 to 3% benzene, although historically some brands had higher concentrations. A large cohort study of British oil and petrol distribution workers followed from 1951 to 1989 found a total of 61 deaths from leukemia with 56.4 expected from national mortality rates (39). On this basis, it appears unlikely that exposure to benzene in this industry accounts for more than one or two cases per year.

There may, in addition, be some cases from the lower but much more widespread exposures that occur in other occupations such as professional drivers. No reliable data are available on the level of risk associated with these lower exposures, but it is probably small.

Mustard Gas

Workers producing mustard gas (for possible use as a weapon of war) have had elevated rates of lung and upper respiratory cancer (40). However, in the United Kingdom manufacture of mustard gas ceased in the 1940s, and it is unlikely that attributable cases now occur in any number.

Mineral Acid Mists

Exposure to mists of strong mineral acids occurs in the manufacture of car batteries, in the pickling of steel before it is plated, and in the chemical industry (e.g., in the production of oleum). High levels of exposure (in excess of 1 mg/m^3 sulfuric acid) are thought to cause cancer of the larynx, and possibly of other sites in the upper respiratory and digestive tracts (41,42). However, relatively few workers

in the United Kingdom have been exposed at this level in recent decades, and the resultant burden of disease is therefore likely to be low. In a recently completed cohort study of 2678 men exposed to acid mists at two steelworks and two battery factories, only one death from laryngeal cancer was recorded during follow-up from as early as 1950; this was close to what would have been expected from national mortality rates (42).

Manufacture of Isopropanol

Manufacture of isopropanol by the strong acid process has been linked with increased risk of nasal cancer (43). Currently, however, only one British company is thought to use this process, with relatively few workers involved.

Ethanol

Consumption of ethanol is well established as a cause of cancers of the liver, oral cavity, pharynx, larynx, and esophagus (44). A number of occupations have clearly elevated rates of alcohol-related diseases, including cancer (Table 2). In most cases the high alcohol consumption in these jobs is not a direct consequence of the work entailed, but rather reflects social influences outside the workplace. And even when a job involves unusual exposure to alcohol (e.g., publicans and barmen), part of the excess may result from selective entry to the occupation of people who already drink heavily. Nevertheless, it is probably reasonable to classify alcohol-related cancers as occupational in some cases. It is plausible that occupational influences might be responsible for 10 to 20 cases per year in the United Kingdom.

Environmental Tobacco Smoke

Some occupations such as publicans and barmen have unusually high exposure to environmental tobacco smoke, and as a consequence may be at increased risk of bronchial carcinoma and other tobacco-related cancers. The burden of disease attributable to this hazard is difficult to assess because of the strong confounding effects of active smoking, but like occupational exposure to alcohol, it might account for some 10 or 20 cases per year.

Other Suspected Occupational Carcinogens

In addition to the well-established causes of cancer that have been discussed, various other occupational exposures are suspected

Table 2. Occupations with high mortality from cancer of the liver and other alcohol related cancers—England and Wales, men 20 to 74 years of age, 1979 to 1980 and 1982 to 1990.[a]

	Cancer of liver		Cancer of oral cavity		Cancer of pharynx		Cancer of esophagus		Cancer of larynx	
Occupation	Deaths	PMR (95% CI)	Deaths	PMR (95% CI)	Deaths	PMR (95% CI)	Deaths	PMR (95% CI)	Deaths	PMR (95% CI)
Lawyers	32	324 (222–458)	12	172 (89–301)	8	151 (65–297)	38	108 (76–148)	11	126 (63–226)
Doctors	40	286 (204–389)	18	184 (109–290)	13	173 (92–296)	59	117 (89–151)	6	48 (18–104)
Literary and artistic occupations	60	155 (119–200)	42	152 (110–206)	33	155 (107–218)	126	93 (78–111)	32	96 (66–135)
Seamen	46	154 (113–205)	56	267 (202–347)	45	279 (203–373)	118	109 (90–131)	67	249 (193–316)
Publicans and barmen	112	184 (152–222)	117	271 (224–325)	71	214 (167–270)	261	119 (105–135)	119	218 (181–261)
Caterers	56	194 (147–253)	26	126 (83–186)	36	227 (159–315)	99	97 (79–118)	31	122 (83–173)
Cooks and kitchen porters	70	254 (198–320)	31	157 (107–223)	54	353 (265–461)	76	79 (62–98)	35	146 (102–203)

Abbreviations: PMR, proportional mortality ratio; CI, confidence interval. [a]Based on Coggon et al. (20).

of causing cancer. These include phenoxy herbicides and structurally related chlorophenols, and electromagnetic fields.

Soft-tissue sarcomas are the tumors that have been linked most consistently with phenoxy herbicides and chlorophenols, but they are rare (approximately 1100 cases per year in England and Wales), and even in the minority of people with heavy occupational exposure, the relative risk is unlikely to be more than 10-fold (45,46). Some studies have also suggested an association between phenoxy herbicides and non-Hodgkin lymphoma, but this finding has been inconsistent (46). A geographical analysis of mortality from non-Hodgkin lymphoma in farmers in England and Wales found no correlation with use of phenoxy herbicides (21) nor was any excess of the disease apparent in a British cohort study of phenoxy herbicide manufacturers and sprayers (47). On balance, therefore, it appears that if these chemicals do cause cancer, then they probably account for fewer than 10 cases per year.

Occupational exposure to electromagnetic fields has been linked particularly with brain cancer (48). This is potentially important because large numbers of people are exposed to such fields in their work. However, the association is a long way from being firmly established, and the mechanisms by which electromagnetic fields might cause cancer are unclear. In national statistics on occupational mortality, the highest rates of brain cancer tend to be in professions such as university lecturers, lawyers, and architects, rather than in electricians and radio and television mechanics (20).

Summary and Conclusions

By far the most important occupational cause of cancer in the United Kingdom is asbestos. Currently some 600 cases of mesothelioma per year may be attributable to asbestos in the workplace, and this number is likely to increase over the next two decades. In addition, occupational exposure to asbestos is responsible for perhaps 100 cases of bronchial carcinoma annually.

Exposure to sunlight in outdoor work may cause several hundred nonmelanomatous skin cancers per year, and occupational exposure to PAHs could be responsible for a similar number of skin and lung tumors. This estimate is subject to considerable uncertainty, however, because of limited information on occupational associations with incident skin cancer and about the risks of lung cancer associated with low levels of exposure.

Other occupational hazards of cancer are either rare or carry only a very low risk at the levels of exposure that now apply, and together are unlikely to account for more than 100 cases per year. Overall, therefore, occupational exposures may be responsible for between 1000 and 2000 of the more than 250,000 cancers that currently occur each year in the United Kingdom.

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